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Aggregate Resources Inventory of the Township of Woolwich Regional Municipality of Waterloo Southern Ontario

By Staff of the Cambridge District Office, Ontario Ministry of Natural Resources, and Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Affairs and Mines

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Aggregate Resources Inventory of the Township of Woolwich Regional Municipality of Waterloo

by Staff[1] of the Cambridge District Office, Ontario Ministry of Natural Resources, and Staff[1] of the Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Affairs and Mines

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Abstract

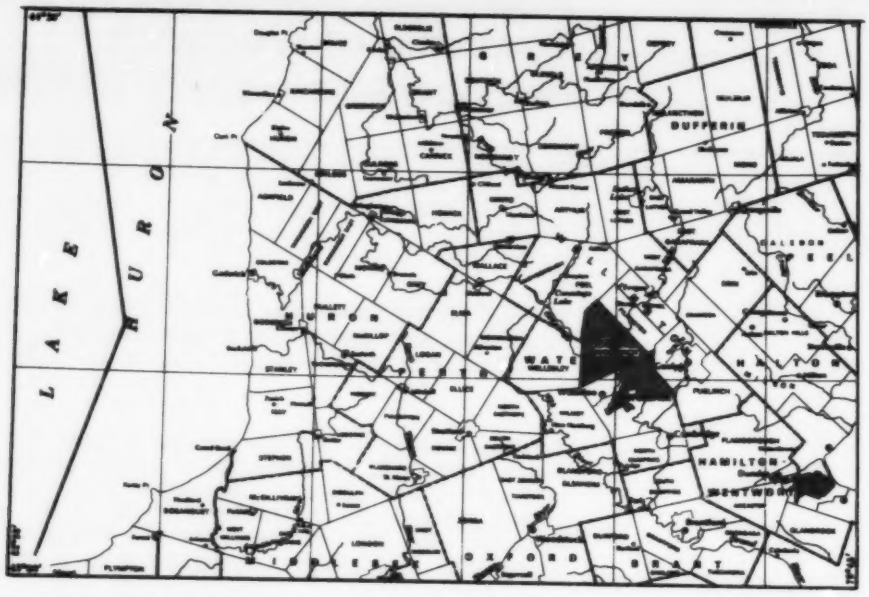


Figure 1. Key Map Showing the Location of the Township of Woolwich, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in the Township of Woolwich. The report is part of the Aggregate Resources Inventory Program for townships designated under the Pits and Quarries Control Act.

In the report area, nineteen areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Resource Areas occupy 7600 acres (3100 ha), exclusive of licenced properties. An estimated 6100 acres (2470 ha) are currently available for extraction, containing possible resources of 247 million tons (224 million tonnes). The parts of the selected areas which are available for extraction represent about 18 percent of the total area occupied by sand and gravel deposits in the municipality and 23 percent of the total resource tonnage.

All but three of the nineteen selected resource areas are outwash deposits associated with the Grand River spillway system. These resource areas usually have uniform, horizontal strata containing high quality gravel and have an average thickness of 10 to 20 feet (3 to 6 m). Generally the sand and gravel may be suitable for granular base course and hot-laid aggregate products, although sand selection and blending may be required (Deike 1982). Deleterious lithologies such as chert are generally absent except in several deposits in the western part of the township.

Bedrock underlying the township consists of Silurian dolostones and shales of the Guelph and Salina Formations. Although dolostone of the Guelph Formation is suitable for the manufacture of various lime products, the excessive thickness of drift prevents any areas from being selected for resource protection.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1982, the total tonnage of mineral aggregates extracted was 101 million tons (92 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing, hand augering and geophysical techniques are used to assess subsurface materials. Airphotos at various scales are used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100- pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests along with petrographic analyses are performed.

Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey. In areas of limited subsurface exposure, test holes are drilled and geophysical surveys using hammer seismic equipment are undertaken. The symbols for and locations of sample and test hole sites along with geophysical traverse lines are noted on Map 1.

In the office, the field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography

maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

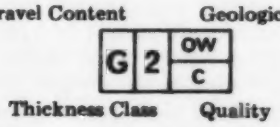
Map 1 is derived from existing surficial geology maps of the area or from airphoto interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, all sand and gravel deposits are outlined and shaded. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The information from which these symbols are derived has been plotted in grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol. Geophysics lines are shown on the map by a line symbol.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light shading on Map 2. Such deposits are believed

to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single, land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the litholgy of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes, pits or sample sites have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the

basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three levels of shading. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource ares. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assùmed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected drill hole which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting

criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approch. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III — Assessment of Aggregate Resources in the Township of Woolwich

LOCATION AND POPULATION

The Township of Woolwich, with an area of 78,819 acres (31 898 ha) is situated in the northeastern corner of the Regional Municipality of Waterloo and includes a major part of the former Waterloo Township. The township is covered by the Conestogo (40 P/10), Stratford (40 P/7), Cambridge (40 P/8) and Guelph (40 P/9) map sheets of the National Topographic System (scale 1:50 000). The area is served by an extensive network of gravel-surfaced township roads, and by paved provincial highways and county roads.

This municipality had a population of 16 363 in 1982, a 16 percent increase from its 1972 population of 14 044 (Ontario Ministry of Municipal Affairs and Housing 1984; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). The local communities of Elmira, St. Jacobs, Conestogo and Breslau, and smaller centres such as Maryhill, Bloomingdale, and West Montrose serve the rural population. Located around the southern perimeter of the township are the municipalities of Guelph, Cambridge, Kitchener and Waterloo. Continued growth in these centres will place additional demands on the aggregate sources in the Township of Woolwich.

Demand for aggregate can be expected to keep pace with current population growth which has been estimated at between 1 and 2 percent (Official Plan, Township of Woolwich 1980). As well, increasing rural-residential development poses a severe constraint on extractive land use, often sterilizing potential mineral aggregate resource areas.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The Grand River meanders through a broad north-south valley which bisects the municipality. West of the river the hummocky rolling terrain is part of the Waterloo Hills (Chapman and Putnam 1984, p.136) and contains ridges of sandy to silty till or ice-contact stratified drift with outwash sands occupying intervening hollows. The Elmira Moraine, near the community of North Woolwich, is the most prominent part of the Waterloo Hills in the township, reaching an elevation of 1375 feet (420 m) from which the land drains southward and eastward to the Conestogo and Grand Rivers, respectively.

Chapman and Putnam (1984, p.137) included the area east of the Grand River as part of the Guelph Drumlin Field. In the report area only a few drumlins are present on the gently undulating till plain. The soils in this area have sandy to silty textures and can be stony, but are generally fertile, easily worked and adaptable to many crops.

The form and distribution of surficial materials, including the sand and gravel deposits outlined on Map 1, are the result of glacial activity that took place in the Late Wisconsinan Substage of the Pleistocene Epoch. During this time period (approximately 23 000 to 10 000 years before present) ice advanced from minor centres in the Great Lakes basins and left a series of end moraines so that the high central part of southwestern Ontario was isolated like an island.

The Township of Woolwich was influenced by ice lobes centred in the Lake Huron-Georgian Bay and Lake Ontario basins. The Elmira Moraine is a complex ridge which formed in an interlobate position, and is believed to have been overridden from the northwest by the Georgian Bay ice lobe depositing a gritty silt unit called the Tavistock Till (Karrow 1971, 1974). The moraine may contain extensive ice-contact and glaciofluvial stratified deposits, but locating viable gravel resources may be difficult because of the predominance of sand-rich material and the variable thickness of the till cap.

East and south of the Elmira Moraine, the Ontario lobe deposited the clayey Maryhill Till and then the silty to sandy Port Stanley Till (Karrow 1971, 1974); the streamlined drumlins of the Guelph Drumlin Field are comprised of Port Stanley Till. These till units have little value as an aggregate source because of their high silt and clay content.

A discontinuous series of hummocky hills along the eastern side of the township (at Breslau and Maryhill) represents brief standstills of the Ontario lobe ice. The Breslau Moraine contains ice-contact and glaciofluvial stratified deposits either at the surface or beneath till. At Maryhill, the morainic materials have been an important source of aggregate for local use.

As the ice sheet receded, eskers containing sand and gravel were deposited near the ice margin. Segments of the Guelph and Ariss esker systems were an important early source of coarse aggregate, but are now largely depleted or inaccessible.

Meltwaters flowing away from the margin of the retreating Ontario ice lobe drained into a major spillway system depositing large quantities of sand and gravel. The Conestogo and Grand River valleys presently occupy the valleys formed by the meltwaters. Numerous terraces, formed by successively lower water levels, contain variable thicknesses of high quality sand and gravel. These deposits are an important existing and future source of aggregate for the region.

Shallow sandy or silty materials occur infrequently in depressions on top of the till plain or spillway materials as a result of temporary pondings during deglaciation.

EXTRACTIVE ACTIVITY

The Township of Woolwich was designated under the Pits and Quarries Control Act on August 15, 1973. At present, twenty-four operations have a total licenced area of 1699.3 acres (687.7 ha). Records at the Cambridge District Office of the Ontario Ministry of Natural Resources indicate that annual production from these licenced sand and gravel operations averaged 400,000 tons (363 000 tonnes) during the period from 1978 to 1981. Aggregate from the pits supplied not only numerous local markets but also the larger regional Kitchener-Waterloo market. Production from wayside sources, opened to meet the requirements of local road authority projects, has

averaged approximately 20,000 tons (18 000 tonnes) over the same time period.

SELECTED SAND AND GRAVEL RESOURCE AREAS

The sand and gravel deposits selected for possible resource protection in the Township of Woolwich are shown on Map 2. Most of these are outwash deposits which formed as part of the glaciofluvial spillway valley now occupied by the present Grand and Conestogo Rivers. Ice-contact and esker deposits have also been selected at the primary level. These selected areas occupy a total of 7600 acres (3100 ha), exclusive of licenced properties. Allowing for cultural constraints, the total sand and gravel resources are approximately 247 million tons (224 million tonnes). The Primary Resource Areas represent 18 percent of the total area occupied by sand and gravel deposits in the township and contain 23 percent of the total resource tonnage.

Outwash deposits associated with the Grand River spillway represent the best quality sources in the report area and present few if any problems for commercial extractive development. These resource areas usually have uniform, horizontal strata containing high quality durable gravel. The deposits have an average thickness of between 10 and 20 feet (3 to 6 m) although this varies from terrace to terrace.

Other selected aggregate deposits of ice-contact origin (kames, eskers) have greater variability, often contain excess sand and may present some workability problems for commercial development.

Sand found in resource areas in the township is usually clean with little intermixing of silt and clay. The sand, however, may require blending for higher specification uses. Although gravel clasts tend to be small in size (2 to 4 inches or 5 to 10 cm) a high stone content allows for excellent crushing prospects. Coarse aggregate quality is generally high, with chert and shaly materials absent or present in only small percentages (exception noted below). Testing by the Ontario Ministry of Transportation and Communications (M.T.C.) has shown that petrographic numbers range from 105 to 134, and the Los Angeles abrasion test results range from 26.0 to 31.0. Magnesium sulphate and absorption tests also indicate that a hard, durable, problem-free aggregate, suited for hot-mix asphalt and structural concrete, can usually be produced (Deike 1982).

High chert contents (up to 20 percent) have been noted in the southwest corner of the township (pit nos. 25 and 28). Because of this, petrographic numbers are higher (143 to 178 in Resource Area 6) and absorption figures are borderline for higher specification uses. The chert noted in the southwestern part of the township (as well as in the adjacent Township of Wellesley) is probably derived from the Bois Blanc Formation which is located west of the report area. Ice moving over the bedrock from the northwest picked up the chert and transported it into the area where it was subsequently deposited by meltwaters. Although small percentages of deleterious constituents such as chert do not detract from the performance of granular base course and similar materials, their presence may render the granular material unsuitable for use in concrete aggregate, unless poorer quality sections are avoided, or unless beneficiation is undertaken (Deike 1982).

Four deposits have also been selected at the secondary level. The deposits were selected at this level because quality factors, such as excess sand, may limit pit development or because only limited information about the deposits is available. Although these areas are not the best deposits in the report area, they contain aggregate that may be useful locally. Consequently, they should be considered as part of the resource base.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Three licenced properties (pit nos. 2, 7, 16) are located in this terraced outwash deposit near West Montrose. Pit faces of 12 to 30 feet (4 to 9 m) reveal horizontal beds of massive or stratified sandy gravel. Gravel content of approximately 50 percent provides a good crushable product although average stone size is generally small. At the southern pit exposures, stratified fine sands overlie massive sandy gravels.

Testing by the M.T.C. has only evaluated the suitability of the deposit for granular base course products. Judging by the general high quality of other deposits in the township, asphalt and concrete specifications can likely be met (Deike 1982), although sand may require blending.

After considering cultural setbacks, 920 acres (370 ha) are available for possible resource extraction. Assuming an overall thickness of 20 feet (6 m), an estimated 46 million tons (42 million tonnes) are available. The deposit is well situated with respect to transportation routes to supply local and regional markets.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Resource Area 2 consists of two outwash deposits which lie in the eastern part of the township. Although similar in character, the two deposits have different thicknesses and have been labelled separately as Area 2a and 2b on Map 2.

Two licenced operations (pits nos. 1 and 17) are found in Area 2a, the thicker, southern outwash deposit. Fifteen-foot (5 m) faces expose two major textural units. The upper unit of 6 feet (2 m) is composed of clean, well sorted, crossbedded fine to medium-coarse sand. The lower massive unit contains sandy gravel with silty sections. These pits have been given a moderate use rating by the M.T.C. and are considered suitable for supplying Granular Base Course (G.B.C.) A, B and C. Evaluation for higher specification uses has not yet been undertaken.

Although no pits have been opened in Area 2b, it is expected that similar aggregate products could be extracted from the material. Water wells indicate that the deposit has an average depth of 10 feet (3 m).

After considering cultural setbacks, the total area available for possible extraction in Area 2 is 580 acres (235 ha). Assuming an overall thickness of 15 feet (5 m) for Area 2a and an average of 10 feet (3 m) for Area 2b, a total of 17 million tons (15 million

tonnes) of sand and gravel are available for resource extraction in the two deposits.

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Resource Area 3 is another terraced outwash deposit along the Grand River valley, east of Conestogo. This deposit has not been tested by the M.T.C. At a nearly depleted licenced property (pit no. 3), a 12-foot (4 m) face reveals uniformly bedded sandy gravel with fine to medium sand lenses. The gravel is of good crushable size which should yield good quality aggregate suitable for granular base products.

After accounting for cultural setbacks associated with limited estate residential development and roads, 600 acres (243 ha) are considered available for possible resource extraction. Assuming an overall deposit thickness of 15 feet (5 m), 22 million tons (20 million tonnes) are well situated for resource extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

This terraced outwash deposit selected for possible resource protection also includes a small indistinct esker segment trending northeast-southwest. Judging by limited pit exposures, the outwash material in the upper terraces may be thin but overlies ice-contact material. A 10-foot (3 m) face in the property licenced to Warren Bitulithic (pit no. 12) shows sandy outwash gravel. Faces at lower levels reveal clean medium to coarse sand. In the resource area, excess sand could present operational problems for extractive development.

This area currently has only limited cultural setbacks and is well situated close to major transportation routes. From an available area of 670 acres (270 ha), it is estimated that 34 million tons (31 million tonnes) are available for possible resource extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 5

Selected Resource Area 5 is a large outwash deposit near the community of Bloomingdale. A 10- to 12-foot (3 to 4 m) face is worked on several terrace levels in pit no. 20. The exposure reveals uniformly bedded gravel with a stone content of 70 percent. The large commercial operation has a moderate-high use rating from the M.T.C. and is considered suitable to supply G.B.C. A, B and C, and with blending, sand for asphaltic aggregate.

After allowing for cultural constraints (see Table 3) approximately 385 acres (156 ha) are available for possible resource protection. Assuming an average deposit thickness of 12 feet (4 m), 12 million tons (11 million tonnes) are present in this resource area.

SELECTED SAND AND GRAVEL RESOURCE AREA 6

Selected Sand and Gravel Resource Area 6 is a Conestogo River valley terrace with a flat, moderately dissected surface. The community of St. Jacobs is partly situated on the deposit. This segment has been delineated by a cultural constraint boundary on Map 2, and deleted from resource calculations.

On the west side of St. Jacobs, a pit formerly operated by Len Goodwin (pit no. 33) exposed well graded gravels in a 10-foot (3 m) face. Test results from the M.T.C. indicated the material was suitable for a variety of granular base products, and with blending, asphaltic aggregate.

Testing by the M.T.C. in the larger portion of the resource area southeast of St. Jacobs (pit nos. 25, 26 and 28) has shown that this material is suitable for most granular base products. There is a relatively high percentage of sand in the deposit, which necessitates selective extraction methods to produce G.B.C. A. The sand also grades coarse and fine, necessitating blending for asphaltic uses.

In this resource area, amounts of chert in the 8 to 15 percent range have been noted, so that poorer quality sections should be avoided. Certain beneficiation measures such as selective crushing or the inclusion of crushed oversize boulders could provide a suitable product for hot-mix asphalt and structural concrete (Deike 1982).

Cultural setbacks and previously extracted areas reduce the area available for possible resource extraction to 400 acres (162 ha). Assuming an overall thickness of 15 feet (5 m), an estimated 15 million tons (14 million tonnes) are well situated with respect to major transportation routes.

SELECTED SAND AND GRAVEL RESOURCE AREA 7

Selected Resource Area 7 is a thinner terrace of the outwash deposit described in Resource Area 1. A largely depleted 28-acre (11 ha) property is licenced to E.S. Hoffer and Sons Ltd. (pit no. 5) is located in the Area. Less than 10 feet (3 m) of gravelly medium sand was exposed in parts of the pit. Other portions contained 20 feet (6 m) of sandy gravel. This pit had a moderate use rating by the M.T.C. and was considered suitable to supply G.B.C. A, B and C. The material, with selection and sand control, could meet specifications for asphaltic uses (Deike 1982).

After allowing for cultural setbacks, an available area of 176 acres (71 ha) contains approximately 5 million tons (4 million tonnes) of aggregate for possible resource extraction. This area is well situated along major transportation routes to supply local and regional markets.

SELECTED SAND AND GRAVEL RESOURCE AREA 8

Selected Resource Area 8 is a moderately dissected outwash terrace lying immediately west of Conestogo. Despite the lack of extractive development, its location and similarity to other Grand River spillway deposits suggest the presence of high quality aggregate.

Cultural setbacks associated with the community of Conestogo reduce the area available for possible resource protection to 285 acres (115 ha). Assuming an overall thickness of 15 feet (5 m), an estimated 11 million tons (10 million tonnes) are available. The deposit is well situated with respect to major transportation routes.

SELECTED SAND AND GRAVEL RESOURCE AREA 9

Selected Resource Area 9 is a terraced outwash deposit lying on the east side of the Grand River. The deposit extends to the northeast into Pilkington Township. Two small pits (pits 38 and 39), with face heights of 18 feet (5 m) and 7 feet (2 m), have been opened to supply local granular road base requirements. These pits contain clean, well graded sandy gravel with a gravel content of approximately 60 percent. No detailed test information is available for this area. Deposit thickness may vary with each terrace.

The resource area contains 540 acres (219 ha), of which 480 acres (194 ha) are available for resource protection. Assuming an average deposit thickness of 15 feet (5 m), approximately 18 million tons (16 million tonnes) are available for possible resource extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 10

This outwash deposit lies west of the community of North Woolwich and is thought to have been derived from Huron-Georgian Bay lobe meltwaters. Test results from the M.T.C. files show that pit no. 31, now depleted and overgrown, was sandy with silty sections and was acceptable for only limited aggregate products. In contrast, testing of the Township of Woolwich licenced property (pit no. 15) on the north side of the road has shown that granular materials are acceptable for a wide range of crushed products including Hot-Laid 4 and 8 asphaltic mixes.

Cultural setbacks reduce the area available for possible extraction to 184 acres (74 ha). Assuming an average deposit thickness of 12 feet (4 m), possible resources are estimated to be 6 million tons (5 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 11

This segment of the Elmira Moraine has a hummocky undulating character, typical of ice-contact deposits. Pit faces in an active and extensively developed property (pit no. 10) reveal highly variable units of sand and lenses of rounded to subrounded gravel. Testing in several areas by the M.T.C. has shown the deposit to be acceptable for a wide range of granular road base aggregate and asphaltic mixes. Sand grades coarse and silty and would require selection and blending for some uses. A chert content of 3 to 5 percent has been noted (Deike 1982).

Cultural setbacks leave 161 acres (65 ha) available for possible resource extraction. Assuming a minimum deposit thickness of 20 feet (6 m), 8 million tons (7 million tonnes) are estimated to be available.

SELECTED SAND AND GRAVEL RESOURCE AREA 12

Situated in the northwestern corner of the township, Sand and Gravel Resource Area 12 is an outwash gravel deposit of moderate thickness. Several unlicenced properties (pit nos. 29, 30, 41 and 42) expose 8 to 25 feet (2 to 8 m) of moderately sorted gravelly sand, with poorly graded and silty sections. Testing by the M.T.C. has rated sources within this deposit as moderate to high. With selection, granular materials may be acceptable for a wide range of products including Hot-Laid 4 and 8 asphaltic mixes and Granular Base Course A, B and C (Deike 1982). Low chert contents (2 to 3 percent in pit 29) have been noted but this should not detract from the overall performance of the aggregate.

This resource area has no major cultural constraints, and can be accessed by paved Regional Road 21. After subtracting cultural setbacks, 164 acres (66 ha) are available for possible extraction, and contain estimated resources of 6 million tons (5 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 13

Selected Resource Area 13 is an outwash terrace situated on the east side of the Grand River valley south of West Montrose. With the exception of one small farm pit (no. 47) there has been no extractive development in the area. Eight to ten feet (2 to 3 m) of well sorted clean gravel is exposed in the upper outwash terrace of this deposit. This deposit, like other outwash terraces along the Grand River, can be expected to yield high quality aggregate suitable for a variety of uses.

After allowing for the very limited cultural setbacks, 270 acres (109 ha) would be available for possible extraction. Assuming an average thickness of 15 feet (5 m), the available aggregate is estimated at 10 million tons (9 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 14

Selected Resource Area 14 is an outwash deposit lying along Hopewell Creek south of Maryhill and is well situated with respect to major transportation routes. One licenced operation (pit 21) is largely depleted. Existing 15-foot (5 m) faces show sandy coarse gravel. Testing by the M.T.C. has shown this area to be acceptable for granular base course products and hot-laid asphaltic stone. The coarseness of the sand fraction observed at the pit may limit its suitability for some uses. Additional aggregate has been obtained below the water table.

After considering cultural setbacks, the total unlicenced area is 156 acres (63 ha). Assuming an overall thickness of 15 feet (5 m), an estimated 6 million tons (5 million tonnes) are available for possible extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 15

Selected Resource Area 15 is a Grand River outwash deposit which extends southward and has also been selected for possible resource protection in the City of Waterloo. Pit faces of 15 feet (5 m) in a licenced gravel pit show sandy coarse gravel. Although detailed test information is not available, the pit should be suitable for a wide range of uses. The variability of the deposit may limit the workability of the pit.

Resource Area 15 occupies 182 acres (74 ha) (exclusive of licenced properties), of which 155 acres (63 ha) are presently available for extraction. Assuming an average thickness of 20 feet (6 m), possible resources of sand and gravel are estimated to be 8 million tons (7 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 16

Selected Resource Area 16 is a Grand River terraced outwash deposit immediately east of Bridgeport. This deposit was initially described as an outwash sand (Karrow 1963) but existing pit exposures (pit nos. 18, 48) show a high gravel content (Bryant and McLellan 1974). No major quality constraints have been noted.

Approximately 375 acres (152 ha) are available for possible resource development, after accounting for cultural constraints. It is estimated that the area contains 14 million tons (13 million tonnes) of sand and gravel.

SELECTED SAND AND GRAVEL RESOURCE AREA 17

Selected Resource Area 17 is a segment of the Guelph esker near Zuber Corners which parallels Regional Road 86. At its western end, an 8.7-acre (3.5 ha) property is licenced to Sittler Excavating Limited (pit no. 11). Several other abandoned and largely overgrown extraction sites have also been identified (pit no. 46). Detailed geological mapping by Bowes (1976) indicated that a massive gravel core was favoured for extraction. Fine to medium sands on the flanks were not often extracted. At the western end, the main esker ridge separates into three ridges. Although the massive gravel core is still present, flanking sections are much more variable and contain crossbedded fine to medium sand, massive sand and silt-clay units. Bowes (1976) suggested that the main ridge of the esker represents a subglacial channel of westward flowing water. Distributary features at the western end represent deposition at an ice margin as the esker stream entered a standing body of water or an outwash channel.

Detailed testing by the M.T.C. has shown that the esker material can supply G.B.C. A, B and C. The massive gravel core presents a suitable crushing source. The pits may, with selection, be suitable to supply Hot-Laid 4 and 8 asphaltic mixes and structural concrete but because of their variable character may contain fine to coarse sand (Deike 1982).

Selected Resource Area 17 is well situated with respect to transportation routes to supply local quantities of high quality aggregate. Total area available for possible extraction is estimated at 99 acres (40 ha) but cultural setbacks and depleted sections reduce the available area to 80 acres (32 ha), which contain an estimated 4 million tons (4 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 18

Selected Resource Area 18 is an outwash terrace which was part of a former spillway system along the Speed River. Parts of this deposit have also been selected as a primary resource in Guelph Township, Puslinch Township and the City of Cambridge. There has been no extractive development in the Woolwich part of the deposit but existing pits in other areas expose 15 feet (5 m) of gravelly sand. These pits have only supplied road sub-base materials in the past and detailed test information is not available.

In Resource Area 18, approximately 61 acres (25 ha) are available for extraction after accounting for cultural setbacks. Assuming an average deposit thickness of 20 feet (6 m), possible resources of sand and gravel are estimated to be 3 million tons (3 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 19

A large gravel ridge of ice-contact stratified drift identified in Pilkington Township extends into the northeastern corner of Woolwich. Although there has been no extractive development in the Woolwich segment, adjacent pit operations show highly variable gravel contents, moderately stratified sand and gravel with silt and fine sand layers. Quality constraints include the presence of oversize material in objectionable quantities and lithologies such as chert and sandstone. The Woolwich portion should be capable of supplying roadbase and surfacing aggregate.

Resource Area 19 has 47 acres (19 ha) available for possible resource extraction, containing an estimated 2 million tons (2 million tonnes) of aggregate.

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Several additional deposits have been selected at the secondary level of significance. Extraction in these deposits may be hindered by operational difficulties imposed by topography, deposit geometry or quality.

Portions of the Guelph esker in the eastern part of the township have been utilized in the past for local needs. The sharply defined ridges have exposed faces varying from 5 to 20 feet (1.5 to 6 m). As with adjacent esker segments (e.g. Resource Area 17), high quality crushable aggregates may be available from gravel cores but flanking sands tend to be fine.

Two esker segments have been selected in the north part of the township. This is an extension of an esker system identified in Peel Township as a primary resource area. Granular base course aggregate has been produced from pit no. 32, although an existing 25-foot (8 m) exposure shows only sandy and silty material.

Two pits (pits 13 and 34) have been opened in an ice-contact deposit west of St. Jacobs. The deposit is very sandy with gravel seams, and in most areas lacks sufficient crushable material to produce G.B.C. A. Sand is too fine in places for asphaltic sand mixes. Testing by the M.T.C. does show that this area could be a suitable source for G.B.C. B and C road base aggregate.

Extraction has occurred at two licenced properties (pits 6 and 9) in a similar ice-contact ridge northwest of Elmira. A gravel core is no longer visible and remaining 15- to 25-foot (5 to 8 m) pit faces show mostly sand. These pits have a low to moderate use rating. With selection, this deposit may be capable of supplying G.B.C. B and C road base aggregate.

Two small outwash deposits on the northeastern boundary of the township are extensions of a larger secondary resource area in Pilkington Township. Although the deposits contain excess silt and clay (Bryant and McLellan 1974), they can produce low-specification aggregate.

BEDROCK GEOLOGY

Dolostones and shales of the Silurian Guelph and Salina Formations underlie Woolwich Township. The formations extend in belts trending north-south (as shown on Map 3) and dip gently to the southwest. The bedrock surface has relief of about 100 feet (30 m), and slopes gradually from north to south to an elevation of about 900 feet (274 m) above sea level near the Waterloo-Wellington Airport (Karrow and Sprague 1976; Karrow et al. 1979; and Miller et al. 1979).

Bedrock does not outcrop within the township and drift thickness is, on average, greater than 100 feet (30 m), but can be as much as 270 feet (82 m). Areas of thin drift cover occur along the Grand River north of West Montrose and south of Breslau, and near Glenchristie, not far from the Speed River valley.

The Guelph Formation underlies the eastern half of the report area and drilling in the area indicates that the Guelph Formation has a maximum thickness of 130 feet (40 m) (Telford 1976, 1979). At outcrops along the Speed River in Guelph and Cambridge and along the Grand River at Elora, the dolostone is usually thick bedded, light brown, and medium to fine crystalline. A reefy facies may also be present. The Guelph Formation is generally soft and not resistant to physical weathering processes, rendering stone unacceptable for production of most road-building or construction aggregates (occasionally, it has been crushed for granular base course or quarried for building stone). However, the dolostone is well suited as a raw material for lime production because of its high chemical purity. The Guelph Formation is quarried at several localities along the Speed River at Glenchristie and Guelph for the manufacture of dolomitic lime used in the production of quicklime and high quality white, hydrated lime. Although areas of Guelph dolostone have been selected for resource protection in adjacent municipalities, excessive thickness of drift overlying the rock prevents any such areas from being identified in Woolwich.

The Salina Formation overlies the Guelph Formation in the western part of the report area. The Salina is composed of soft grey shale and thin- to medium-bedded dolostone with numerous seams and lenses of gypsum. Drilling records indicate a thickness of approximately 330 feet (100 m) for the unit (Telford 1979). Although the Salina is not suitable for production of crushed aggregate, it has economic value as a source of gypsum and is being mined at Hagersville, Caledonia and Drumbo. A study of drill cuttings from oil and gas exploration wells failed to show a significant concentration of gypsum in the Regional Municipality of Waterloo (only a few drill hole records were available for study) (Guillet 1983). No areas have been selected for possible resource protection.

SUMMARY

The Township of Woolwich has sand and gravel resources which are, and will continue to be, important regional sources for road-building and construction aggregates. Nineteen areas selected for possible resource protection contain approximately 247 million tons (224 million tonnes) of granular material which are capable of providing a variety of high quality products. Five resource areas of secondary significance have also been identified. Care should be taken to ensure the continued availability of as much of these areas as possible.

The township is underlain by bedrock of the Guelph and Salina Formations. Although the Guelph dolostone has value as a raw material for the production of chemical lime, excessive drift cover prevents any areas from being selected for resource protection.

Enquiries regarding the Aggregate Resources Inventory of the Township of Woolwich should be directed to the Ontario Ministry of Natural Resources either at the Cambridge District Office, Box 2186, Cambridge, Ontario, N3C 2W1 (Tel. (519) 658-9355), or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203), or to the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Affairs and Mines, Room M1B-45, MacDonald Block, Queen's Park, Toronto, M7A 1W3, (Tel. (416) 965-1663).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, TOWNSHIP OF WOOLWICH.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
1	G-OW	1570 (635)	78 (71)
	G-K	610 (247)	30 (28)
	S-K	6100 (2470)	305 (275)
2	G-OW	8300 (3350)	295 (270)
	G-E	157 (64)	6 (5)
	G-K	415 (168)	16 (14)
	S-OW	3600 (1460)	124 (113)
	S-K	1720 (700)	65 (59)
3	G-OW	3350 (1360)	59 (53)
	G-E	129 (52)	2 (2)
	G-K	390 (158)	7 (6)
	S-OW	3900 (1580)	60 (54)
4	G-OW	1230 (500)	15 (14)
	G-E	145 (59)	2 (2)
	S-OW	1150 (465)	12 (11)
	S-K	44 (18)	<1 (<1)
		33,000 (13 400)	1080 (980)

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF WOOLWICH.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
1	G09-174	W. Aberle	Pt. 129	GCT*	56.9 (23.0)	15 (5)	40
2	G09-035	John A. Carlaw Const. Ltd. & George Dietrich Const. Ltd.	Pt. 71 1	GCT WGR	9.4 (3.8)	15 (5)	20
3	G09-161	John A. Carlaw Const. Ltd. & George Dietrich Const. Ltd.	Pt. 7	Broken Front E.G.R. Crooks Tract	2.7 (1.1)	12 (4)	60
4	-	I.M. Martin	Pt. 28	GCT	10.0 (4.0)	5 (1.5)	–
5	C12-049	E.S. Hoffer & Sons Ltd.	52	GCT	27.6 (11.2)	10-20 (3-6)	30 (depleted)
6	-	E.S. Hoffer & Sons Ltd.	90	GCT	2.3 (0.9)	25 (8)	40
7	G09-078	E.S. Hoffer & Sons Ltd.	69,72	GCT	31.8 (12.9)	20-30 (6-9)	40
8	G09-162	E.E. Seegmiller	1	GCT	40.0 (16.2)	13 (4)	60
9	-	Sittler Excav. Ltd.	90	GCT	11.0 (4.4)	15 (5)	35
10	C12-061 C12-058	Sittler Excav. Ltd.	93,94	GCT	36.0 (14.6)	20 (6)	40
11	G09-045	Sittler Excav. Ltd.	74	GCT	8.7 (3.5)	30 (9)	30
12	-	Warren Bitulithic	Pt. 12,13	Chalmers Block	65.0 (26.3)	10-20 (3-6)	30
13	C12-101 C12-013	Nelson Brubacher	Pt. 40	GCT	6.7 (2.7)	25 (8)	30
14	G09-055	Twp. of Woolwich	Pt. 81	GCT	14.0 (5.7)	30 (9)	65
15	C12-059	Twp. of Woolwich	Pt. 98	GCT	11.1 (4.5)	12 (4)	50
16	G09-163	Twp. of Woolwich	Pt. 67	GCT	11.0 (4.4)	12 (5)	50
17	G09-047	R. Nikelski	Pt. 129	GCT	52.7 (21.3)	15 (5)	45
18	G01-297	Blacktop Const. Ltd.	Pt. 112,113	GCT	92.0 (37.2)	15 (5)	65
19	G01-006	Forwell Ltd.	114-116	GCT	521.0 (210.8)	20 (6)	60
20	G09-011	Preston Sand & Gravel	Pt. Oxbow Pt. 6 & 7 J.W.T.	Beasley's Upper Block	550.0 (222.6)	10-12 (3-4)	70

*GCT Germany Company Tract

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF WOOLWICH.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
21	G09-038	E.E. Seegmiller Ltd.	Pt. 83	GCT & Hornings Tract	35.0 (14.2)	15 (5)	50
22	G01-298	M.R. Jutzi	Pt. 116	GCT	20.6 (8.3)	15 (5)	60
23	-	A. Schnurr	Pt. 81	GCT	26.6 (10.8)	20 (6)	40
24	-	460328 Ont. Ltd.	Pt. 4 & 5	GCT	57.2 (23.1)	12 (4)	-
					1699.3 (687.7)		
UNLICENCED PITS*							
25	C12-002	O. Martin	4,5	GCT		15 (5)	65
26	C12-012	U. Martin	4	GCT		15 (5)	65
27	G09-041	I. Martin	69	GCT		15 (5)	45 (overgrown)
28	C12-39	E. Martin	6	GCT		14 (4)	65 (unopened)
29	C12-057	Soehner	97	GCT		15 (5)	40 (overgrown)
30	C12-045	Schwindt	121	GCT		12 (4)	40 (overgrown)
31	C12-060	Bowman	99	GCT		11 (3)	30 (overgrown)
32	-	Brubacher	122	4A		10-25 (3-8)	20
33	C12-024	Goodwin	8,9	GCT		14 (4)	75 (depleted)
34	C12-015	S. Bowman	39	GCT		30 (9)	25
35	C12-029	A. Martin	20	GCT		16 (5)	40
36	-	H. Eix	102	GCT		10 (3)	20
37	-	-	83	GCT		5-10 (1.5-3)	50
38	-	A. Brohman	7	A		18 (5)	60
39	-	-	6	Hitchings Tract		7 (2)	60 (overgrown)
40	C12-107	-	58	GCT		12 (4)	5
41	-	-	124	GCT		8 (2)	60

*Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF WOOLWICH.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
42	C12-104	-	124	GCT		10-25 (3-8)	40
43	-	A. Ritschel	63	GCT		5 (1.5)	20
44	-	-	3	5		20 (6)	30
45	-	C. Martin	3	Hitchings Tract		8 (2)	40
46	G09-034	Melitzer	126	GCT		20-50 (6-15)	50 (depleted)
47	G09-156	-	75	GCT		8-10 (2-3)	50
48	-	Bluevale Farms	71	Hornings Tract		10-15 (3-5)	60

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, TOWNSHIP OF WOOLWICH.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
1	1090 (440)	173 (70)	1 (1)	920 (370)	20 (6)	46 (42)
2a	205 (83)	85 (34)	<1 (<1)	120 (49)	15 (5)	5 (4)
2b	495 (200)	35 (14)	0 (0)	460 (186)	10 (3)	12 (11)
3	760 (310)	160 (65)	0 (0)	600 (243)	15 (5)	22 (20)
4	790 (320)	116 (47)	0 (0)	670 (270)	20 (6)	34 (31)
5	440 (178)	53 (21)	0 (0)	385 (156)	12 (4)	12 (11)
6	540 (218)	93 (38)	45 (18)	400 (162)	15 (5)	15 (14)
7	240 (97)	64 (26)	0 (0)	176 (71)	12 (4)	5 (4)
8	395 (160)	108 (44)	0 (0)	285 (115)	15 (5)	11 (10)
9	540 (219)	54 (22)	1 (1)	480 (194)	15 (5)	18 (16)
10	255 (103)	49 (20)	22 (9)	184 (74)	12 (4)	6 (5)
11	181 (73)	20 (8)	1 (1)	161 (65)	20 (6)	8 (7)
12	275 (111)	84 (34)	27 (11)	164 (66)	15 (5)	6 (5)
13	315 (127)	47 (19)	1 (1)	270 (109)	15 (5)	10 (9)
14	184 (74)	27 (11)	1 (1)	156 (63)	15 (5)	6 (5)
15	182 (74)	27 (11)	0 (0)	155 (63)	20 (6)	8 (7)
16	460 (186)	84 (34)	1 (1)	375 (152)	15 (5)	14 (13)
17	99 (40)	10 (4)	9 (4)	80 (32)	18 (6)	4 (4)
18	64 (26)	3 (1)	0 (0)	61 (25)	20 (6)	3 (3)
19	47 (19)	0 (0)	0 (0)	47 (19)	20 (6)	2 (2)
	7600 (3100)	1420 (575)	107 (43)	6100 (2470)		247 (224)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNSHIP OF WOOLWICH

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
25-50 (8-15)	Guelph	60 (18)	790 (320)	171 (155)

TABLE 5. QUARRIES, TOWNSHIP OF WOOLWICH.

1 NO.	2 MTC NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

-NONE-

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, TOWNSHIP OF WOOLWICH.

1 **DEPOSIT NO.**	2 **DEPTH OF OVERBURDEN** Feet (Metres)	3 **UNLICENCED AREA** Acres (Hectares)	4 **CULTURAL SETBACKS** Acres (Hectares)	5 **EXTRACTED AREA** Acres (Hectares)	6 **AVAILABLE AREA** Acres (Hectares)	7 **ESTIMATED WORKABLE THICKNESS** Feet (Metres)	8 **AVAILABLE RESOURCES** Millions of Tons (Tonnes)
-NONE-							

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Cambrian: The first period of the Palezoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed

aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic Era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear de-

posits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near- ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine- grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin- bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive- bedded, fine-to medium-grained dolostone.

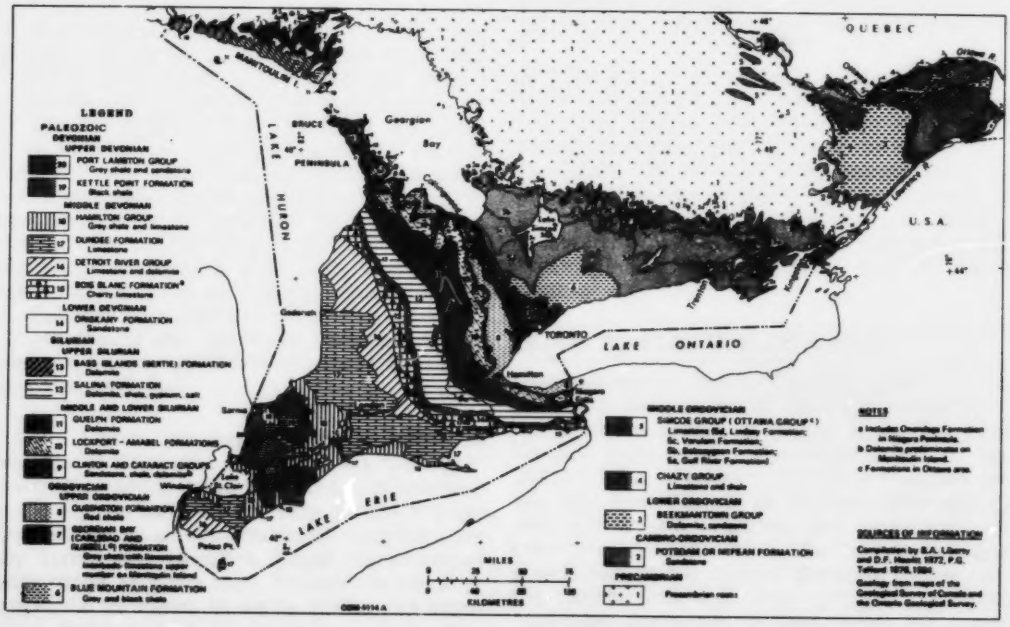


Figure 2. Bedrock Geology of Southern Ontario.

Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium- grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey- brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to microcrystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician) (Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

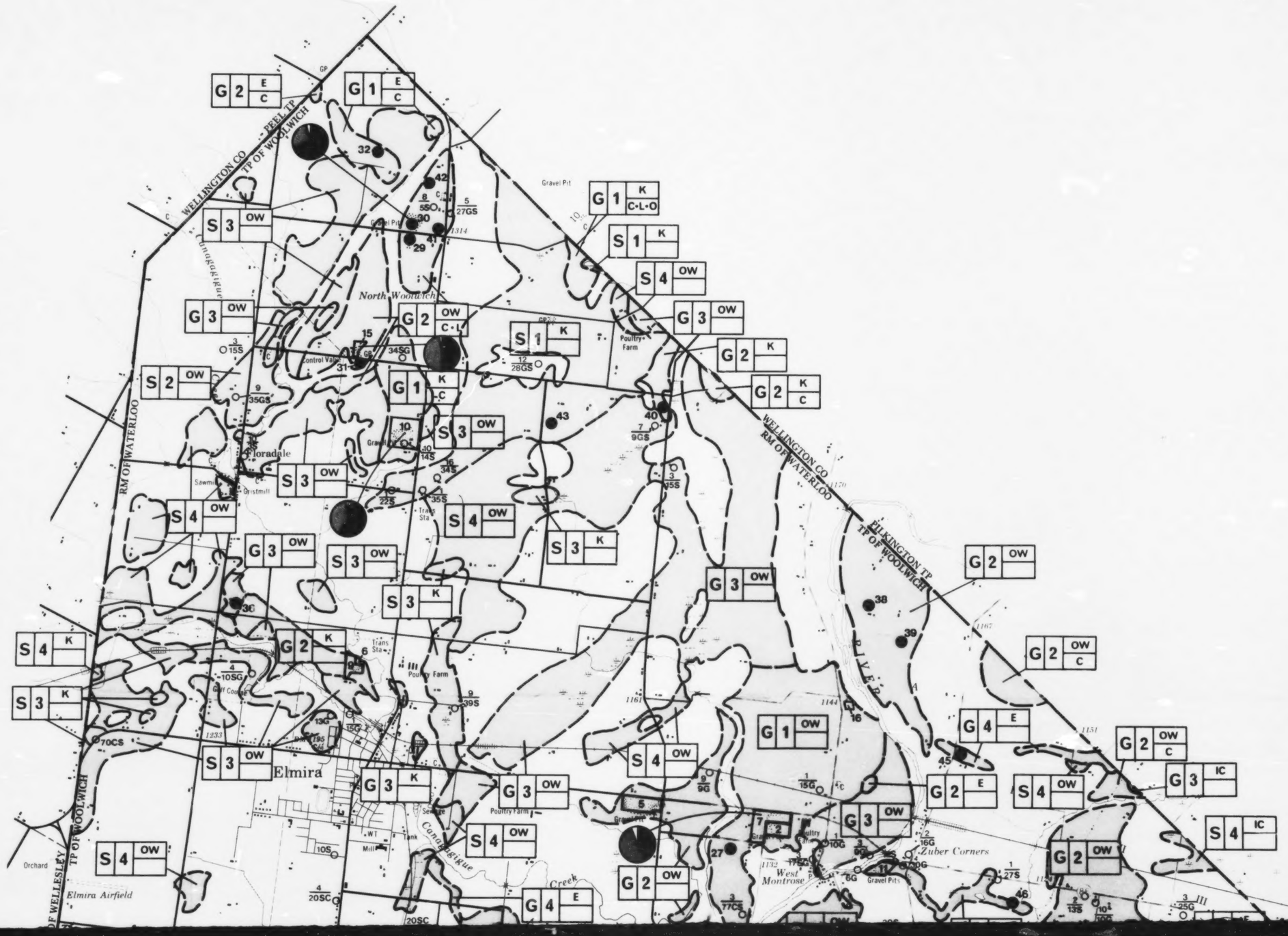
Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.


PEEL TP
TP OF WOOLWICH
WELLINGTON CO
RM OF WATERLOO
WELLINGTON TP
TP OF WOOLWICH
TP OF WELLESLEY
North Woolwich
Floradale
Elmira
Elmira Airfield
West Montrose
Zuber Corners
Gravel Pit
Poultry Farm
Trans Sta
Gristmill
Orchard
Control Valve
Golf Course
Creek
RIVER
G 2 E C
G 1 E C
S 3 OW
G 1 K C-L-O
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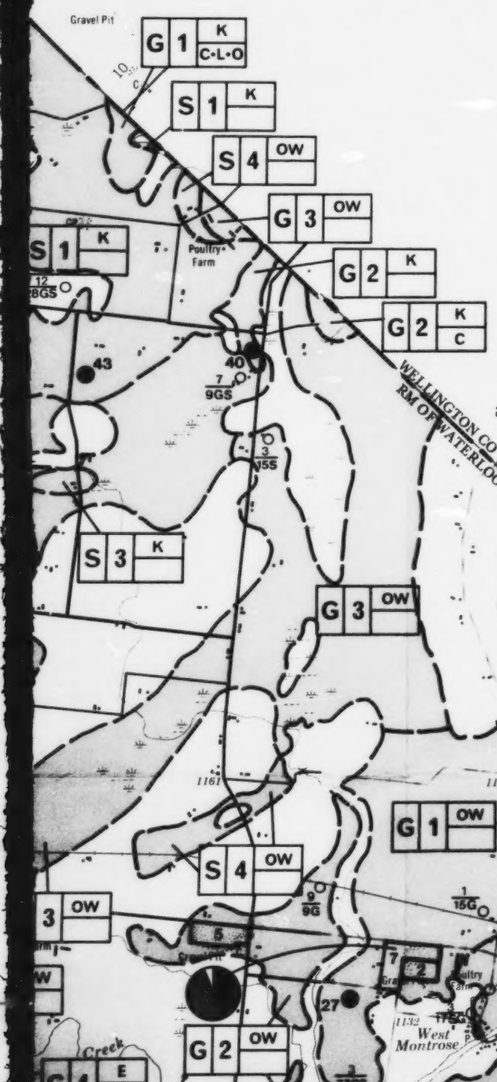
Gravel Pit
G 1 K C·L·O
S 1 K
S 4 OW
G 3 OW
S 1 K
Poultry Farm
G 2 K
G 2 K C
WELLINGTON CO
RM OF WATERLOO
ELLINGTON TP
TP OF WOOLWICH
S 3 K
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G 2 OW
G 2 OW C
G 1 OW
G 4 E
S 4 OW
G 2 E
G 3 OW
G 2 OW C
G 3 IC
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West Montrose
Gravel Pits
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RIVER
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N

Ministry of
Northern Affairs
and Mines

Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF WOOLWICH

REGIONAL MUNICIPALITY OF WATERLOO

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/7, 40 P/8
40 P/9, 40 P/10

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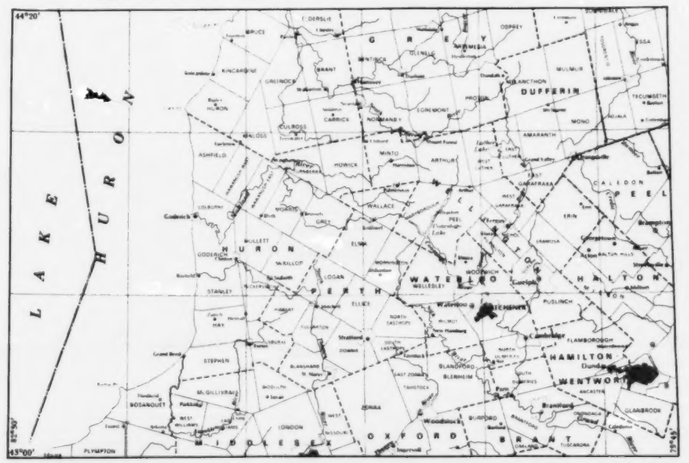


Location Map

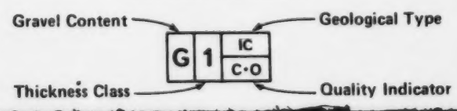
Scale: 1:800,000

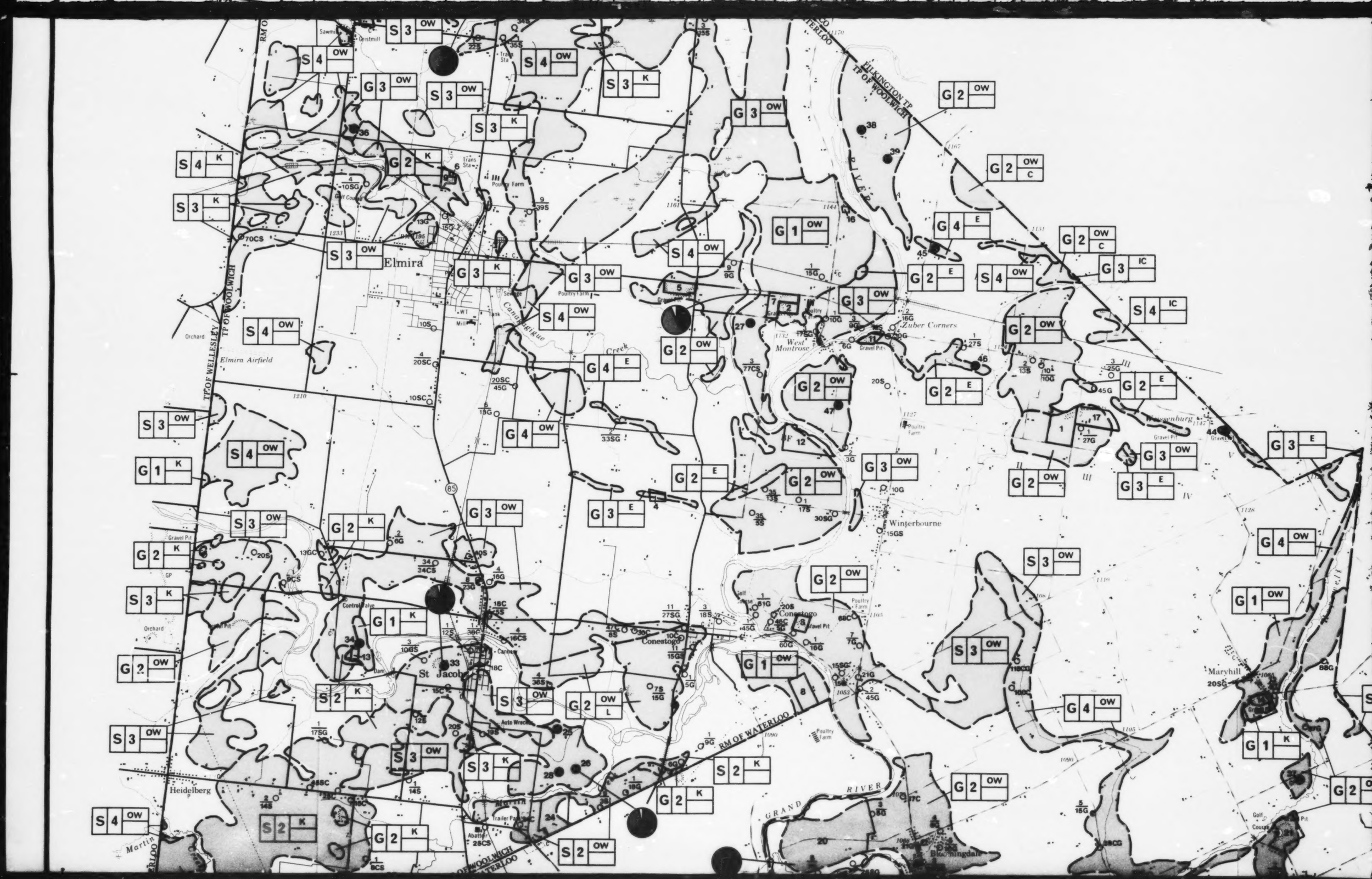
SYMBOLS

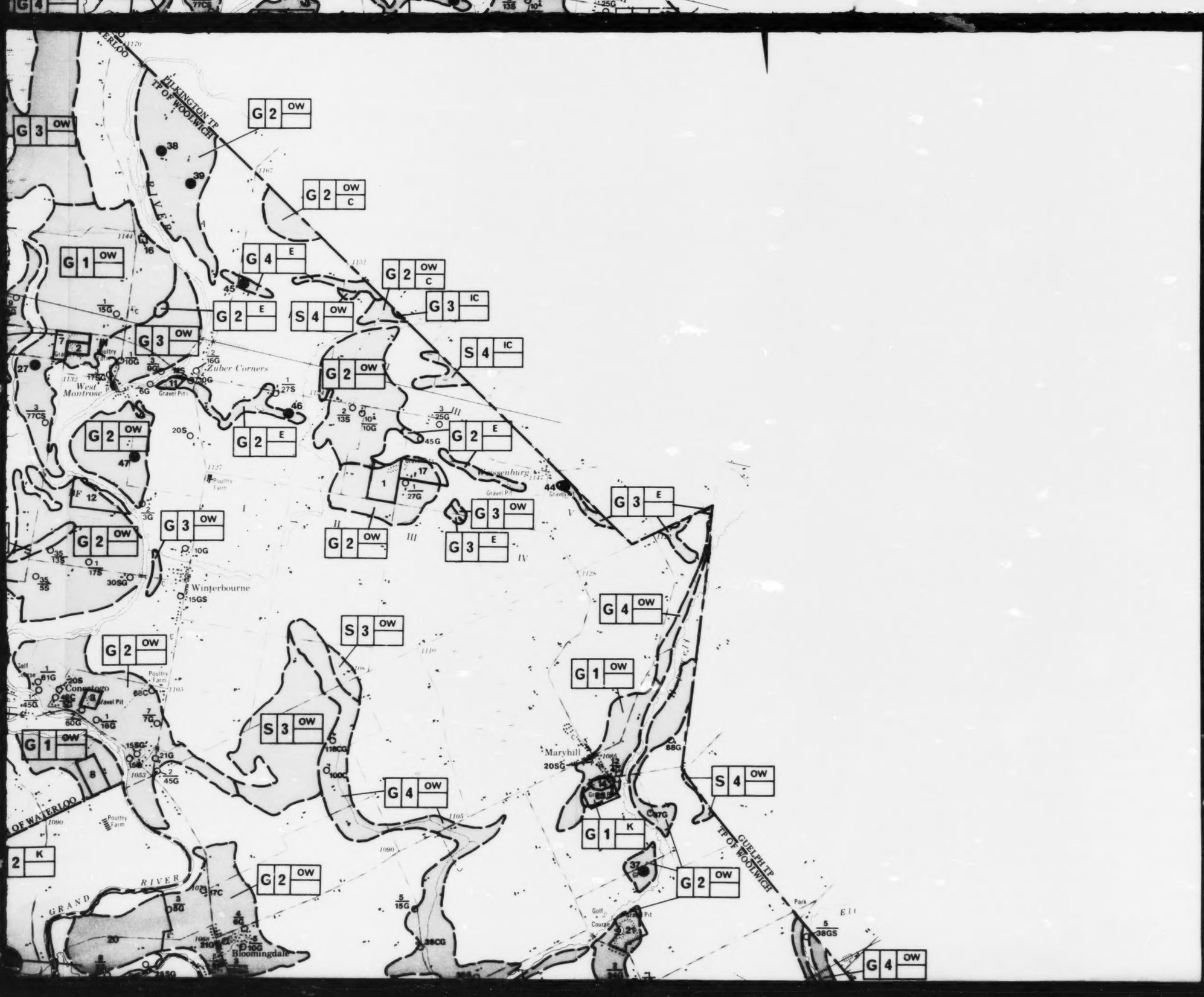
(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

DEPOSIT SYMBOL




Elmira
St Jacobs
Conestogo
Winterbourne
Maryhill
Heidelberg
Bloomingdale
Wasserburg
West Montrose
Zuber Corners
Elmira Airfield
Orchard
Gristmill
Sawmill
Trans Sta
Poultry Farm
Gravel Pit
Golf Course
Trailer Park
Abattoir
Auto Wrecker
Sewage
Mill
Dam
Canagagigue Creek
GRAND RIVER
RM OF WATERLOO
TP OF WELLESLEY
TP OF WOOLWICH
ELLINGTON TP
RIVER
Martin



Location Map

SYMBOLS

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Geological and aggregate thickness bound indicates deposit area.

Buried geological and aggregate thickne Shading indicates deposit area.

Municipal boundary.

2 — Licenced property boundary; Property Table 2.

3 — Unlicenced sand or gravel pit*; Property Table 2.
*Abandoned pit or wayside pit operatin under authority of a permit.

WW-TH-2 — Selected test hole location; Identificat see Table 7.

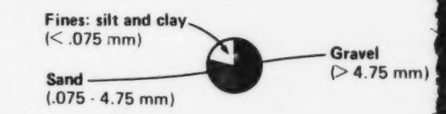
6/23G — Selected drilled water well location; re ness of material (in feet); reported typ (number only - overburden, T - till, G sand, C - clay, Bk - bedrock).

G 1 IC / C-O — Deposit Symbol: see below.

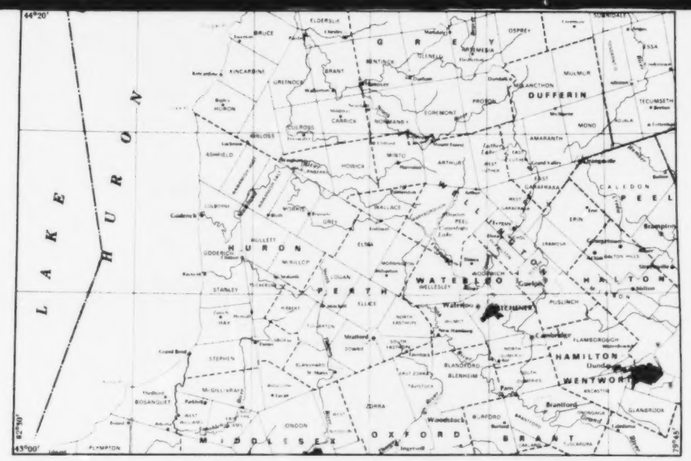
Texture symbol: see below.

TEXTURE SYMBOL

(This symbol is used where sample analysis data are availa



The Texture Symbol provides quantitative assessment of th distribution at a sampled location. The relative amounts of silt and clay in the sampled material are shown graphically by th of a circle into proportional segments. The above example sh thetical sample consisting of 45% gravel, 35% sand and 20%



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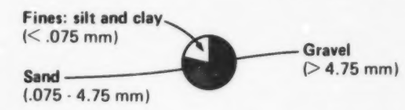
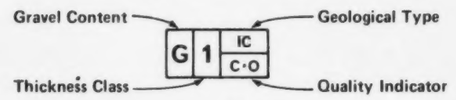


The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL



Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12, 500 (< 28 000)

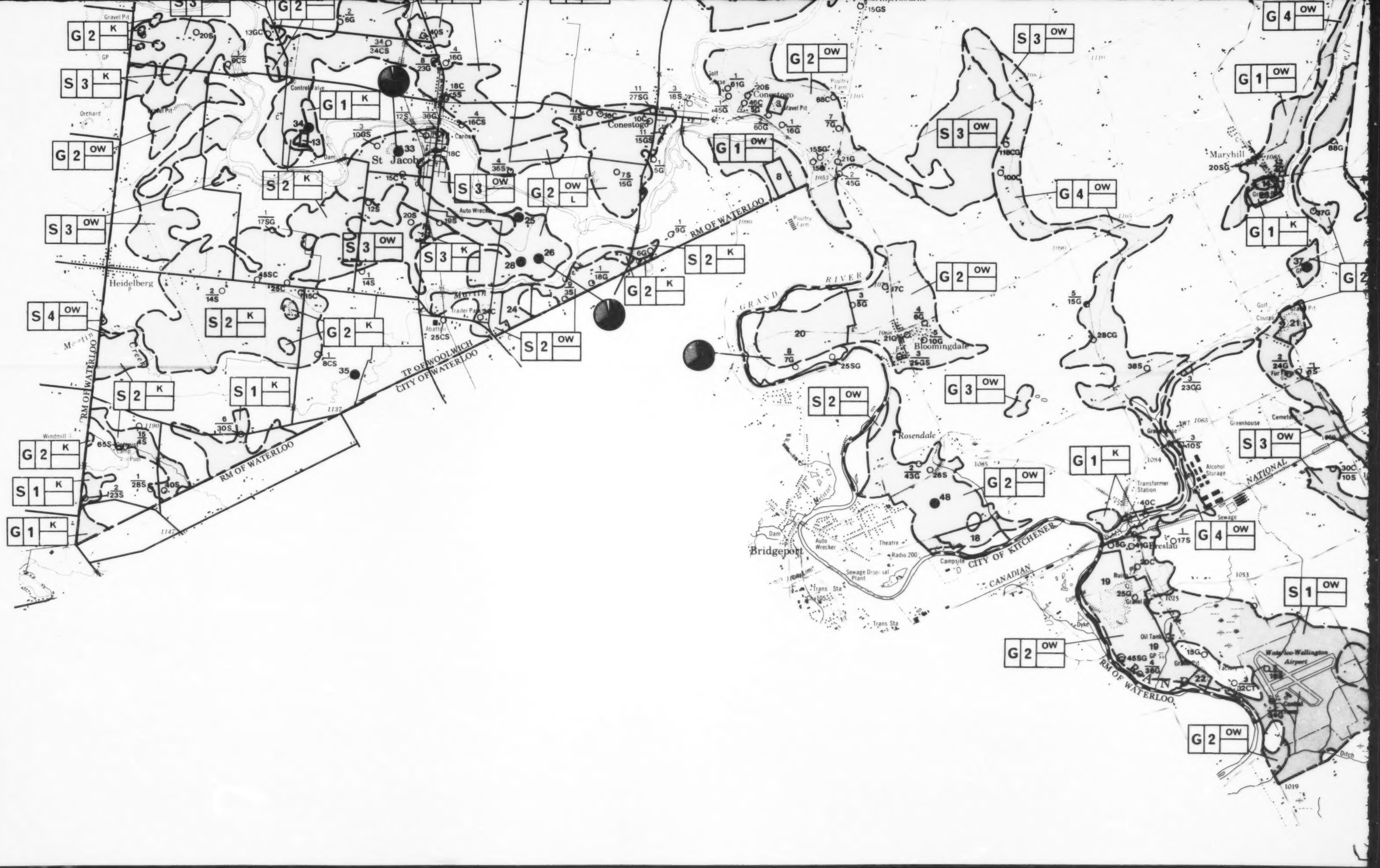
Geological Type

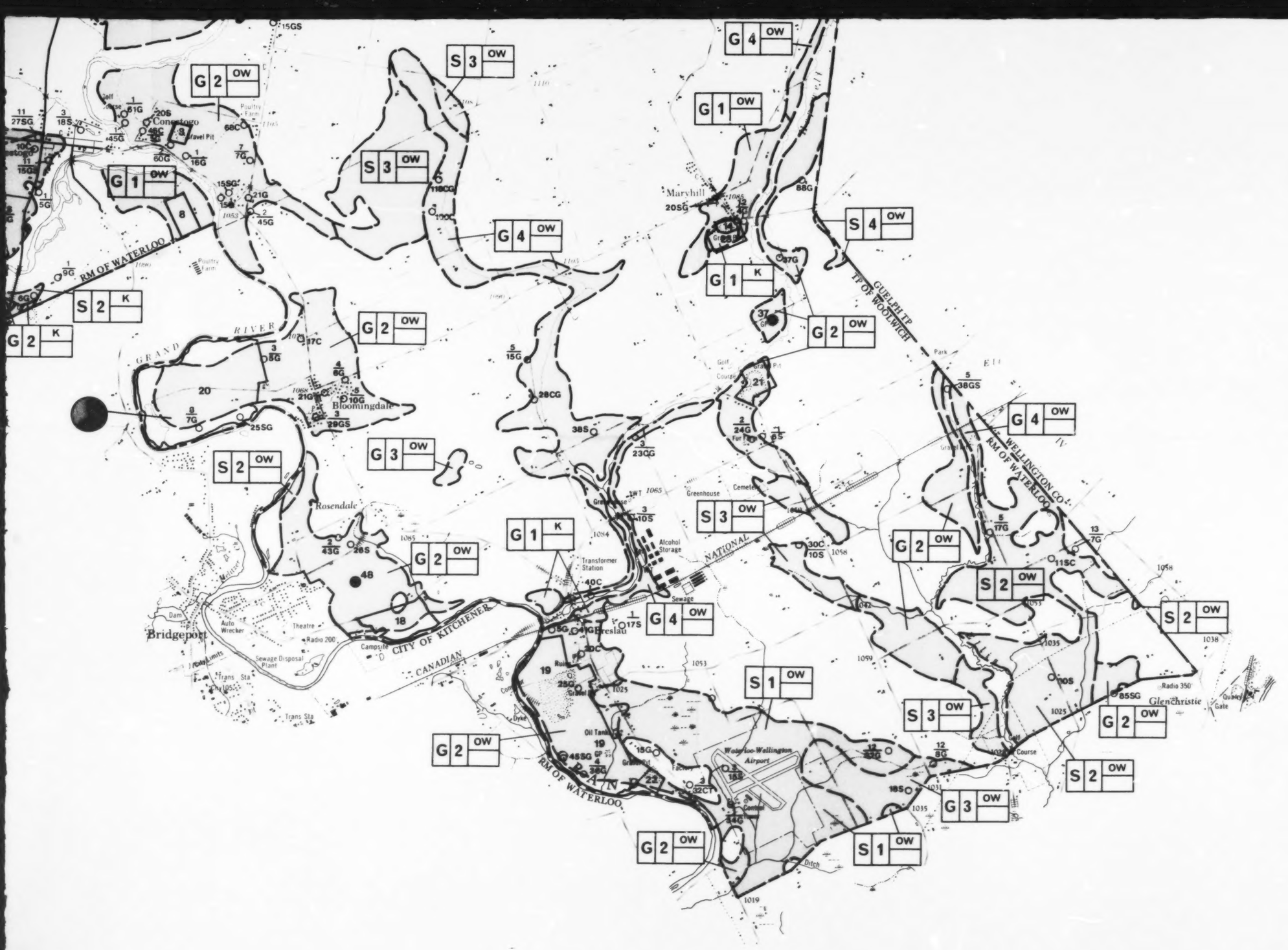
AL	Older Alluvium	**K**	Kame
E	Esker	**LB**	Lacustrine Beach
EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	**WD**	Windblown Forms

(see Appendix C for descriptions of Geological Types)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.


RM OF WATERLOO
CITY OF WATERLOO
TP OF WOOLWICH
CITY OF KITCHENER
RM OF WILMOT
RM OF WOOLWICH
GRAND RIVER
CANADIAN NATIONAL
Heidelberg
St Jacobs
Conestogo
Maryhill
Bloomingdale
Rosendale
Bridgeport
Waterloo-Wellington Airport
Gravel Pit
Trailer Park
Auto Wrecker
Sewage Disposal Plant
Transformer Station
Alcohol Storage
Greenhouse
Cemetery
Golf Course
Campsite
Radio 200
Trans Sta
Oil Tanks
Ditch
Dyke
Dam
Pond
Windmill
Orchard
Poultry Farm
Abattoir
Sewage
Theatre
Creslau



WW-TH-2 Selected test hole locat
see Table 7.

6 / 23 G Selected drilled water w
ness of material (in feet
(number only - overbur
sand, C - clay, Bk - bedro

G 1 IC / C-O Deposit Symbol: see belo

Texture symbol: see belo

TEXTURE SYMBO

(This symbol is used where sample analy

Fines: silt and clay (< .075 mm)

Sand (.075 - 4.75 mm)

The Texture Symbol provides quantitative distribution at a sampled location. The relati silt and clay in the sampled material are shown of a circle into proportional segments. The a thetical sample consisting of 45% gravel, 35%

Base map by Surveys and Mapping Branch, On sources.

Licence data from District and Regional Office Resources.

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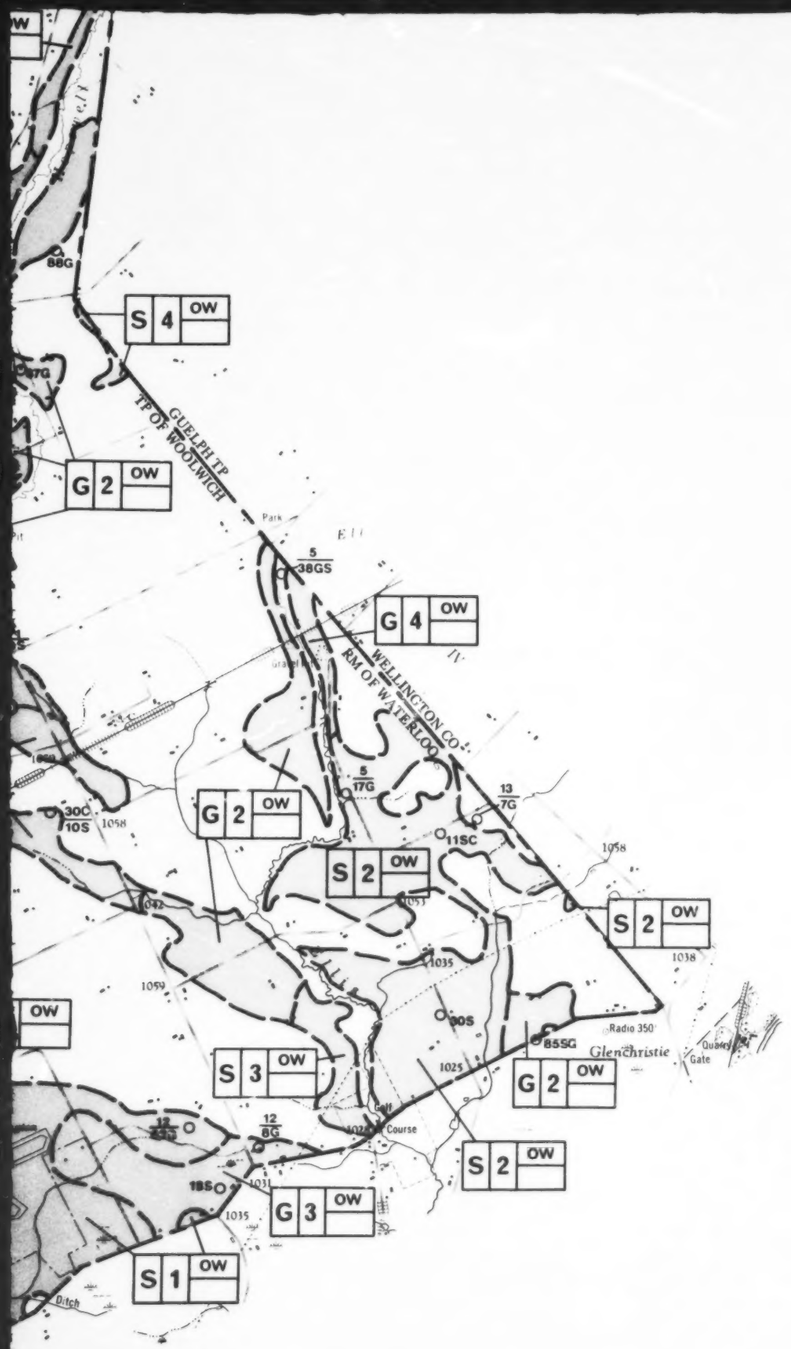
Test hole data from Aggregate Assessment Offic Ontario Ministry of Natural Resources.

Selected drilled water well data from the Ontario

Drilling data from the Petroleum Resources Natural Resources.



WW-TH-2 — Selected test hole location; Identification number: see Table 7.

O 6/23G — Selected drilled water well location; reported thickness of material (in feet); reported type of material (number only - overburden, T - till, G - gravel, S - sand, C - clay, Bk - bedrock).

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SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

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Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Natural Resources.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P. F. Karrow, 1958, 1971, 1983.

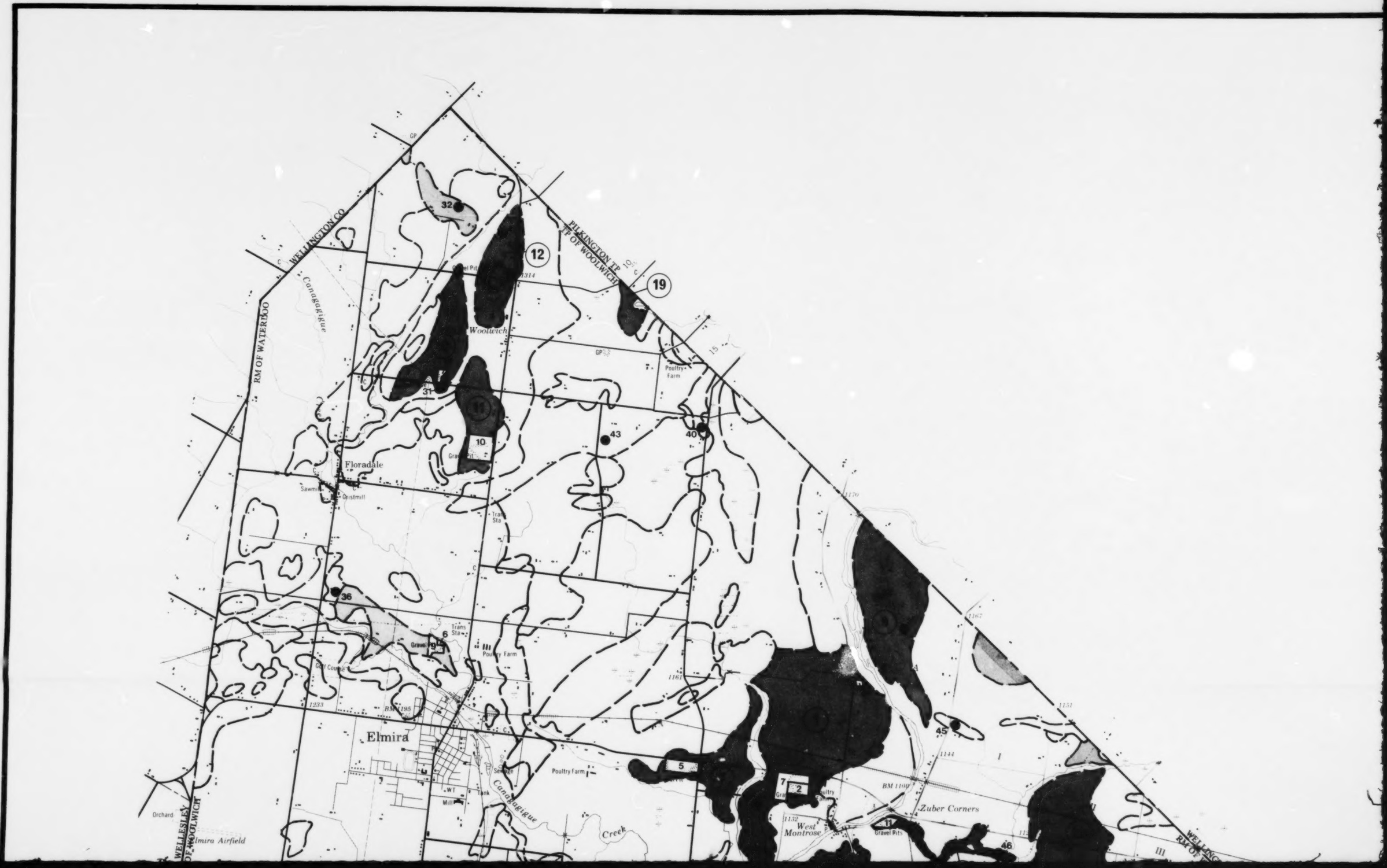
Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ministry of Northern Affairs and Mines.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 103.

This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.

Issued 1985.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.


WELLINGTON CO
RM OF WATERLOO
PILKINGTON TP
TP OF WOOLWICH
Conagagitague
Woolwich
Floradale
Sawmill
Gristmill
Trans Sta
Poultry Farm
Gravel Pit
Golf Course
Elmira
BM 1195
Sewage
Mill
Tank
Orchard
Elmira Airfield
Conagagitague Creek
West Montrose
Zuber Corners
BM 1109
Gravel Pits
WELLESLEY
TP OF WOOLWICH
RM OF

Ministry of
Northern Affairs
and Mines

Ontario

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF WOOLWICH

REGIONAL MUNICIPALITY OF WATERLOO

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/7, 40 P/8
40 P/9, 40 P/10

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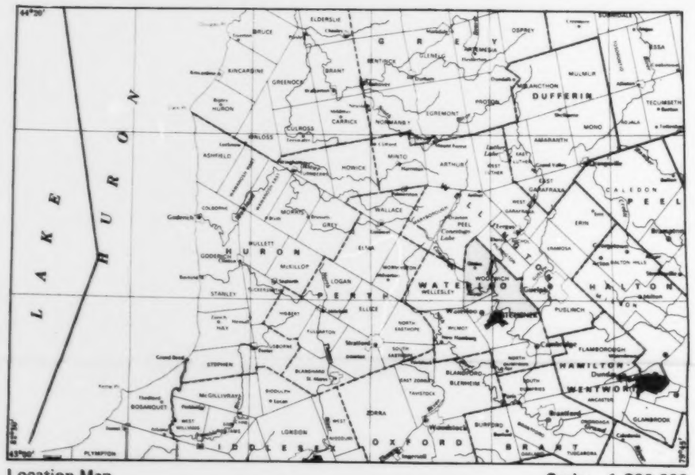


Location Map Scale: 1:800,000

SYMBOLS

(Some symbols may not apply to this map.)

— — — — Geological and aggregate thickness boundary.

•••••••••••••••••• Buried geological and aggregate thickness boundary.

Elmira

Heidelberg

Winterbourne

Zuber Corners

West Montrose

Maryhill

Martin

Elmira Airfield

Creek

Canagagigue Creek

GRAND RIVER

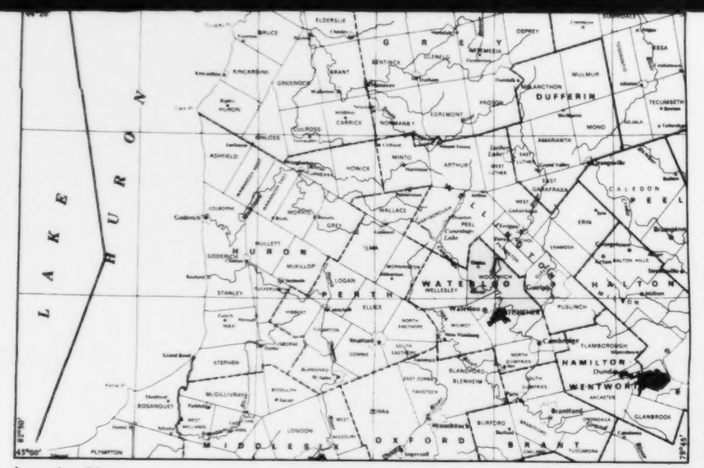
TP OF WELLESLEY

TP OF WOOLWICH

RM OF WATERLOO

WELLINGTON CO

Cultural Constraint Boundary



Location Map

Scale: 1:800,000

SYMBOLS

(Some symbols may not apply to this map.)

- Geological and aggregate thickness boundary.
- Buried geological and aggregate thickness boundary.
- Municipal boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- 2 — Licenced property boundary; Property number: see Table 2.
- 3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
  *Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: P. F. Karrow, 1968, 1971, 1983.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 103.

This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.

Cultural Constraint

Boundary

RM OF WATERLOO

TP OF WOOLWICH

CITY OF WATERLOO

CITY OF KITCHENER

Heidelberg

Bridgeport

Maryhill

Breslau

Rosendale

Martin

GRAND RIVER

CANADIAN NATIONAL

Waterloo-Wellington Airport

WOOLWICH

● 3 Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
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Issued 1985.

WELLINGTON CO
TP OF WOOLWICH
FEEL TP
RM OF WATERLOO
Canagagigue Creek
Gravel Pit
1314
North Woolwich
GP
186
Control Valve
C
132
SALINA FORMATION
Floradale
Sawmill
Gristmill
Trans Sta
88
Poultry Farm
PILKINGTON TP
TP OF WOOLWICH
1170
50
1167
RIVER A
WELLINGTON CO
RM OF WATERLOO
1151
1161
1141
GUELPH FORMATION
183
Golf Course
1233
BM 1195
Elmira
Sewage
Canagagigue Creek
Poultry Farm
Gravel Pit
Gravel Pits
BM 1100
1144
I
II
III
Zuber Corners
77
1132
West Montrose
1124
Orchard
Elmira Airfield

Ministry of Northern Affairs and Mines

Ontario

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF WOOLWICH

REGIONAL MUNICIPALITY OF WATERLOO

MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/7, 40 P/8
40 P/9, 40 P/10

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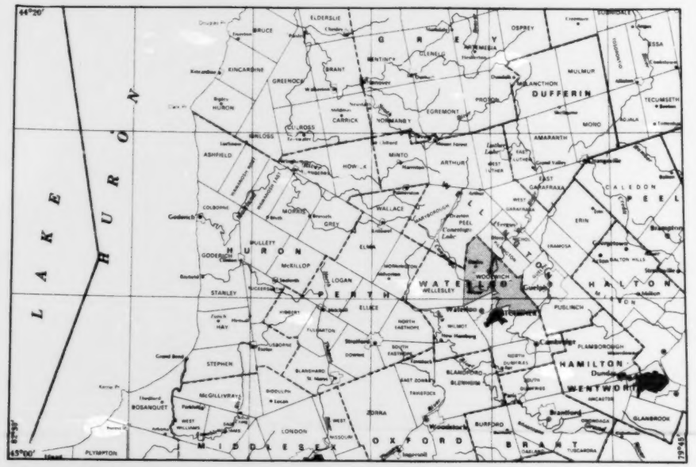


Location Map Scale: 1:800,000

LEGEND

PALEOZOIC

SILURIAN

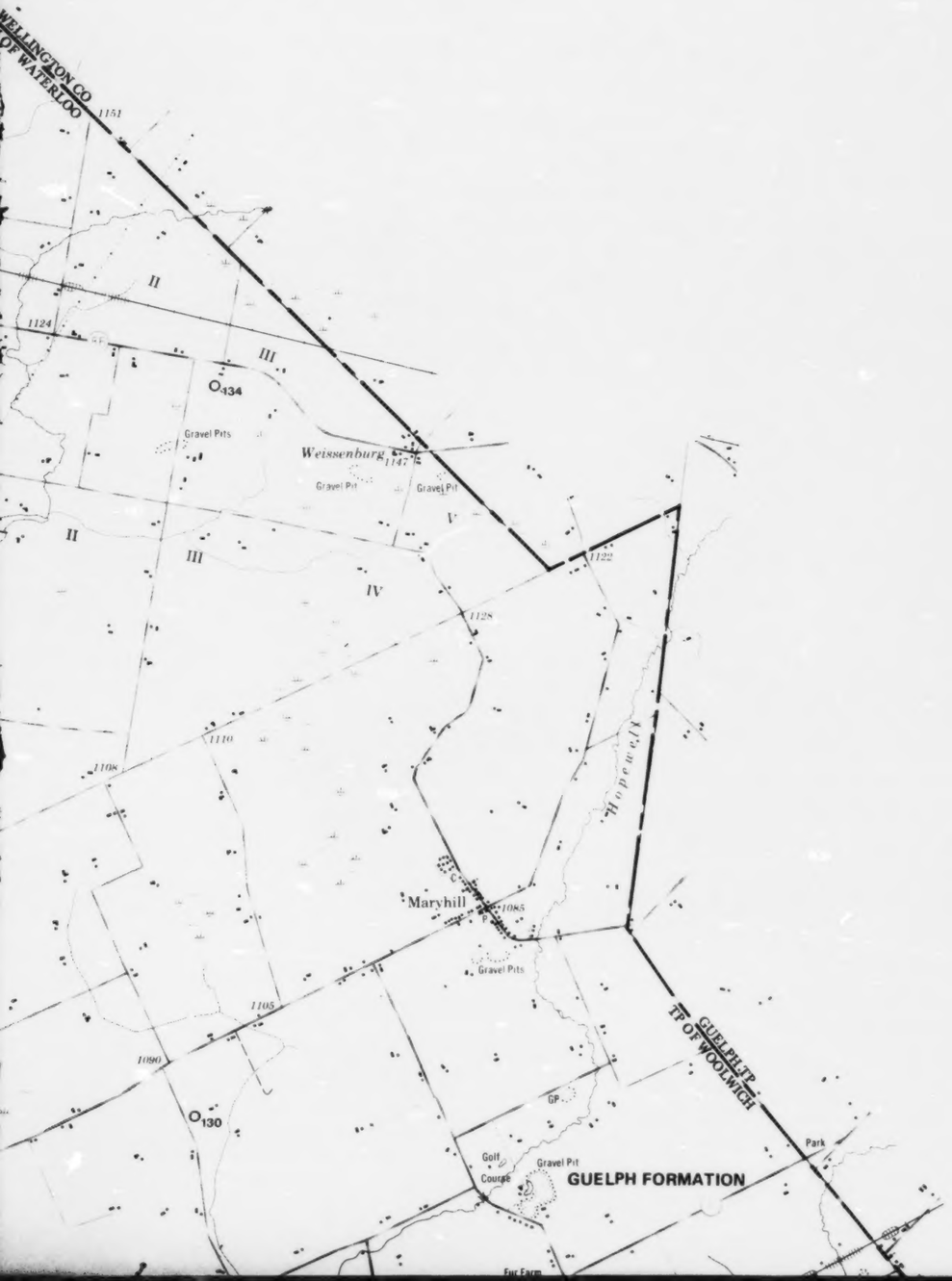
UPPER SILURIAN

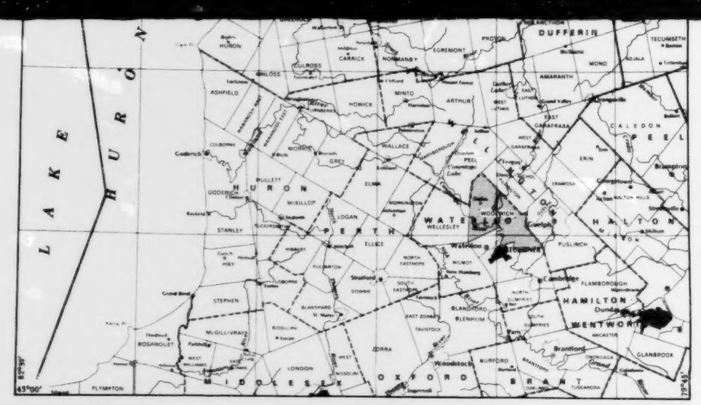
SALINA FORMATION
Dolostone, shale, gypsum, salt

MIDDLE SILURIAN

Elmira Airfield

Sawmill
Gristmill
Trans Sta
Gravel Pit
Poultry Farm
Golf Course
BM 1195
Elmira
Sewage
Tank
Mill
WT
Canagagigue Creek
Orchard
Elmira Airfield
GP
TP OF WELLESLEY
TP OF WOOLWICH
RM OF WELLINGTON
RM OF WATERLOO
GUELPH FORMATION
SALINA FORMATION
RIVER A
Gravel Pits
Zuber Corners
West Montrose
BF
Weissenburg
Winterbourne
Golf Course
Conestogo
Control Valve
Canopy
Dam
St Jacobs
Auto Wrecker
Martin Creek
Trailer Park
Abattoir
Heidelberg
Poultry Farm
Maryhill
Hopewell
GRAND RIVER
Bloomingdale
Gravel Pit
Golf Course
GUELPH FORM
Fox Farm





Location Map

Scale: 1:800,000

LEGEND

PALEOZOIC

SILURIAN

UPPER SILURIAN

SALINA FORMATION
Dolostone, shale, gypsum, salt

MIDDLE SILURIAN

GUELPH FORMATION
Dolostone

SYMBOLS

(Some symbols may not apply to this map.)

Geological formation boundary.

Geological formation member boundary.

Formation thickness boundary (see text).

25 — Drift thickness contour: 25 foot (8 m) interval.

Municipal boundary.

2 — Selected bedrock resource area; Deposit number: see Table 6.

Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.

Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.

Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.

x — Isolated bedrock outcrop.

Q2 — Licenced quarry boundary; Property number: see Table 5.

Q3 — Unlicenced quarry*; Property number: see Table 5.
*Abandoned quarry or wayside quarry operating on demand under authority of a permit.

Gravel Pit
GP
Orchard
Gravel Pit
Control Valve
Dam
St Jacobs
Canbery
Auto Wrecker
Martin
Trailer Park
Abattoir
Creek
Heidelberg
Martin
Creek
Windmill
Optimist Camp
Pool
RM OF WATERLOO
TP OF WOOLWICH
CITY OF WATERLOO
RM OF WATERLOO
Conestogo
Golf Course
Conestogo
Gravel Pit
Poultry Farm
Maryhill
Gravel Pits
Poultry Farm
GRAND RIVER
Bloomingdale
Golf Course
Gravel Pit
GUELPH FO
Fur Farm
Greenhouse
Greenhouse
Cemetery
Rosendale
Alcohol Storage
Transformer Station
NATIONAL
Sewage
Bridgeport
Auto Wrecker
Theatre
Radio 200
Sewage Disposal Plant
Trans Sta
Trans Sta
CITY OF KITCHENER
CANADIAN
Breslau
Ruins
Gravel Pit
Oil Tanks
Gravel Pit
Factory
Waterloo-Wellington Airport
Control Tower
Ditch
50
GRAND

WOOLWICH

(Some symbols may not apply to this map.)

- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).
- 25 — Drift thickness contour: 25 foot (8 m) interval.
- Municipal boundary.

- (2) Selected bedrock resource area; Deposit number: see Table 6.
- Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.
- Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.
- X Isolated bedrock outcrop.
- Q2 Licenced quarry boundary; Property number: see Table 5.
- ● Q3 Unlicenced quarry*; Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- O 28 Selected drilled waterwell location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P. F. Karrow, R. F. Miller and L. Farrell, 1979.
P. F. Karrow and D. J. Sprague, 1976a, b.
R. F. Miller, L. Farrell and P. F. Karrow, 1979.
B. V. Sanford, 1969.
P. G. Telford, 1976, 1979.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ministry of Northern Affairs and Mines.

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